MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2022/2023 (TERM ID 2210)

ETM4166 – RADIO NETWORK PLANNING TOWARDS 5G

(TE)

6 FEBRUARY 2023

2:30 P.M – 4:30 P.M.

(2 Hours)

INSTRUCTIONS TO STUDENT:

1. This exam paper consists of **9 pages** (including cover page) with **3 questions**.
2. Attempt **ALL questions**. The breakdown of marks within each question is given.
3. Please write all your answers in the answer booklet provided. Show all relevant steps to obtain maximum marks

Question 1

The link budget for a UMTS cell is given in the table below:

	Notation	Unit	Downlink
Target load	l	%	75
User bit rate	R	kbps	144
Transmitter			
Max. power per connection	P_t	Watt	6
TX antenna gain	G_t	dBi	18
TX cable loss	L_t	dB	2
Transmitter EIRP	$EIRP$	dBm	
Receiver			
Thermal noise density	N	dBm/Hz	-174
Receiver noise figure	F	dB	7
Interference margin	η	dB	
Total noise power (thermal + interference)	P_N	dBm	
Processing gain	PG	dB	
Required E_b/N_0	E_b/N_0	dB	7
Receiver sensitivity	P_{sens}	dBm	
RX antenna gain	G_r	dBi	0
Antenna diversity gain	G_d	dB	0
Soft handover gain	G_{ho}	dB	1
RX cable loss	L_r	dB	0
Other Margins and Gains			
Location probability	P_L	%	95
Slow fading standard deviation	σ	dB	6
Slow fading margin	L_{sf}	dB	
Body loss	L_b	dB	2
Building penetration loss	L_p	dB	7
Maximum allowable path loss (MAPL)	$MAPL$	dB	

a) For the downlink link budget, find the followings:

i. Transmitter EIRP [2 marks]
ii. Interference margin [2 marks]
iii. Total noise power (thermal + interference) [2 marks]
iv. Processing gain [2 marks]
v. Receiver sensitivity [2 marks]
vi. Slow fading margin [2 marks]
vii. maximum allowable path loss [3 marks]

b) The downlink load can be modeled as

Continued...

$$\eta = \sum_{n=1}^{N} \alpha_n \frac{(E_b/N_0)_n}{(PG)_n}(1 - v + i)$$

where

N is the total number of users
α_n is the activity factor of the nth user
$(E_b/N_0)_n$ is the required SNR of the nth user
$(PG)_n$ is the processing gain of the nth user
v is the orthogonality factor of the codes
i is the intercell interference

Suppose the system settings are given in part (a) and let $\alpha_n = 1$ for all users, $v = 0.9$ and $i = 0.55$. What is the maximum number of users that can be supported for downlink?

[5 marks]

c) Coverage of a UMTS network needs to be improved when the network is coverage-limited in the uplink or downlink direction. Give two approaches for improving the UMTS coverage.

[2 marks]

d) Select True or False for the following statements about the differences between the WCDMA and GSM air-interfaces:

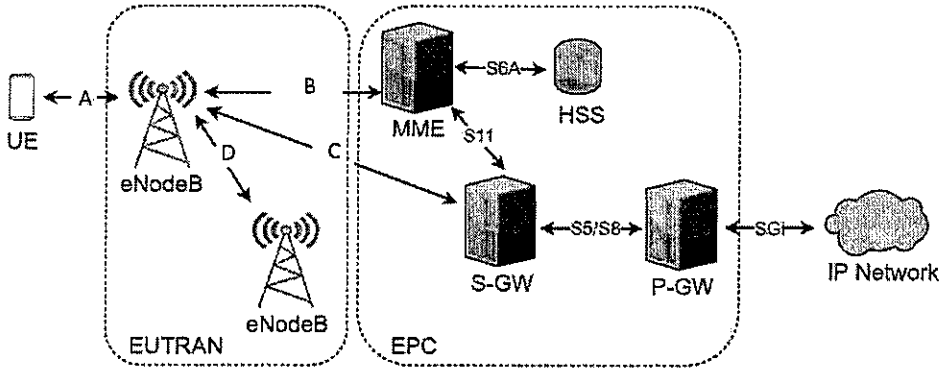
Statement	True/False
i) Only one frequency channel is used in WCDMA while GSM uses many frequency channels.	
ii) Users are separated by time in WCDMA while GSM uses a combined time and frequency approach for supporting multiple users	
iii) Packet data scheduling in WCDMA is load based while in GSM it is timeslot based	

[3 marks]

Continued...

Question 2

a) The following figure shows the LTE network architecture:



i) State the name of the interfaces indicated by A, B, C and D.

[4 marks]

ii) Match the correct function to each of the network elements given below:

Function	Network element
1. All control plane functions related to subscriber and session management.	eNodeB
2. Provide subscriber profile and authentication information	MME
3. Anchor point for sessions towards the external packet data networks	S-GW
4. Radio resource control and radio mobility management	P-GW
5. Mobility anchor point for inter-eNB handover and for inter-3GPP mobility.	HSS

[5 marks]

b) Design targets for the uplink of an urban LTE cell are given in the table below:

Criteria	Target
Required cell edge throughput	512 kbps
MIMO configuration	1T2R
Required SINR (at cell edge)	-1.8 dB
Assigned number of resource blocks	10
MCS Index	3
Block error rate (BLER)	10%
Receiver noise figure	3 dB
G-factor (or minimum SIR)	-1 dB
Adjacent cell load	70%

Continued...

i) Based on the Transport Block Size table given in the Appendix, determine the expected data rate (in kbps) at the cell edge.

[2 marks]

ii) Find the receiver sensitivity at cell edge.

[4 marks]

iii) Suppose additional system parameters are given in the following table:

	Notation	Unit	Value
eNB antenna gain	G_R	dBi	18
Cable & connector losses	L_c	dB	0.5
Shadowing margin	L_{sf}	dB	8
Handoff gain	G_{ho}	dB	3
Building penetration loss	L_{bp}	dB	20
Body loss	L_b	dB	0
UE antenna gain	G_T	dBi	0
UE max transmit power	P_T	dBm	23

Find the maximum acceptable path loss (MAPL).

[4 marks]

iv) Suppose the LTE cell is operating at 1800 MHz and the heights of eNB and UE are 30 m and 1.5 m respectively, determine the cell range based on COST 231-Hata model.

[4 marks]

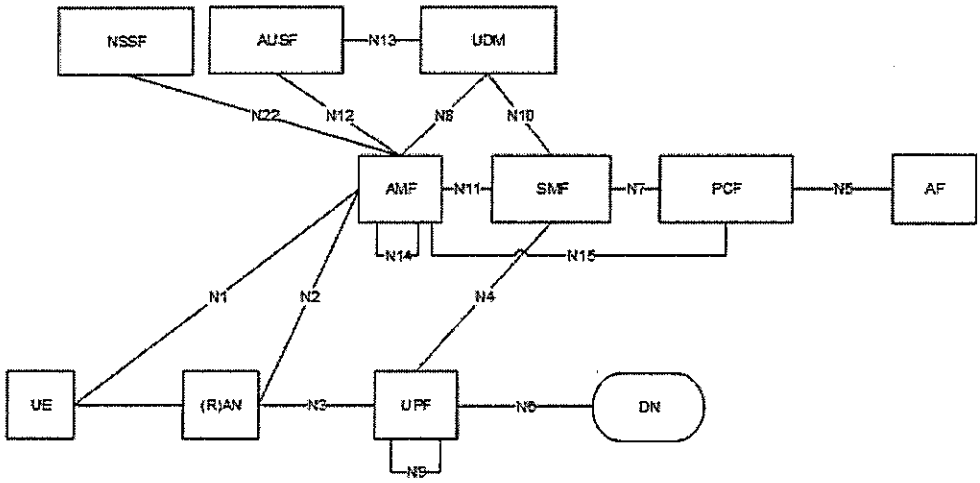
c) State two new functionalities introduced in LTE-Advanced (LTE-A).

[2 marks]

Continued...

Question 3

a) An illustration of the 5G network architecture is given below:



i) Give the full name of the network functions UPF, AMF, SMF and AUSF.

[4 marks]

ii) Match the correct description to each of the network functions given below:

Function	Network function
1. It is equivalent to the connection management (CM) and mobility management (MM) sub-layers of the MME (of LTE).	UPF
2. It is responsible for IP address allocation, session bearer management and charging.	AMF
3. It is equivalent to the gateway of SGW+PGW (of LTE). Data is transferred from here to an external network.	SMF
4. It authenticates UEs and stores authentication keys.	AUSF

[4 marks]

b) Consider a 5G NR operating in FR1 with subcarrier spacing of 30 kHz and channel bandwidth of 50 MHz. Show that the number of available resource blocks (RBs) is 133. (Hint: For channel bandwidth of 50 MHz, the required guard band is 1045 kHz)

[4 marks]

Continued...

c) Downlink and uplink transmission of 5G NR are organized into frames. Each frame consists of 10 subframes. The number of slots within one subframe depends on the numerology (μ) adopted. Suppose $\mu = 1$, with normal cyclic prefix and SCS of 30 kHz, find the number of slots per subframe, the duration of one slot, and the number of OFDM symbols per subframe.

[4 marks]

d) Briefly explain how MIMO and beamforming can be used to overcome the coverage and interference limitation of the 5G networks.

[4 marks]

End of Paper

Appendix

Table A.1 Log-normal fading margin as a function of location probability at cell edge

Location probability at the cell border, %	Lognormal fade margin, dB
50	$\sigma \times 0$
60	$\sigma \times 0.25$
70	$\sigma \times 0.52$
80	$\sigma \times 0.84$
90	$\sigma \times 1.28$
91	$\sigma \times 1.34$
92	$\sigma \times 1.4$
93	$\sigma \times 1.48$
94	$\sigma \times 1.55$
95	$\sigma \times 1.64$
96	$\sigma \times 1.75$
97	$\sigma \times 1.89$
98	$\sigma \times 2.05$
99	$\sigma \times 2.33$

Table A.2 Transport block size table

I_{TBS}	N_{PRB}						
	6	10	15	25	50	75	100
0	152	256	392	680	1384	2088	2792
1	208	344	520	904	1800	2728	3624
2	256	424	648	1096	2216	3368	4584
3	328	568	872	1416	2856	4392	5736
4	408	696	1064	1800	3624	5352	7224
5	504	872	1320	2216	4392	6712	8760
6	600	1032	1544	2600	5160	7736	10296
7	712	1224	1800	3112	6200	9144	12216
8	808	1384	2088	3496	6968	10680	14112
9	936	1544	2344	4008	7992	11832	15840
10	1032	1736	2664	4392	8760	12960	17568
11	1192	2024	2984	4968	9912	15264	19848
12	1352	2280	3368	5736	11448	16992	22920
13	1544	2536	3880	6456	12960	19080	25456
14	1736	2856	4264	7224	14112	21384	28336
15	1800	3112	4584	7736	15264	22920	30576
16	1928	3240	4968	7992	16416	24496	32856
17	2152	3624	5352	9144	18336	27376	36696
18	2344	4008	5992	9912	19848	29296	39232
19	2600	4264	6456	10680	21384	32856	43816
20	2792	4584	6968	11448	22920	35160	46888
21	2984	4968	7480	12576	25456	37888	51024
22	3240	5352	7992	13536	27376	40576	55056
23	3496	5736	8504	14112	28336	43816	57336
24	3624	5992	9144	15264	30576	45352	61664
25	3752	6200	9528	15840	31704	46888	63776
26	4392	7480	11064	18336	36696	55056	75376

Table A.3 Path loss models

Model	Expression	Remarks
Free space	$PL = -27.55 + 20\,log_{10}(f) + 20\,log_{10}(d)$	f is in MHz, d is in m
Okumura-Hata	$PL = A + B\,log_{10}\,d + C$ where $A = 69.55 + 26.16\log_{10} f - 13.82\log_{10} h_b - a(h_m)$ $B = (44.9 - 6.55\log_{10} h_b)$ Small and medium-size cities (urban) $a(h_m) = (1.1\log_{10}(f) - 0.7)\,h_m - (1.56\log_{10}(f) - 0.8)$ $C = 0$ Metropolitan areas $a(h_m) = \begin{cases} 8.29(\log_{10}(1.54h_m))^2 - 1.1 & f \le 200MHz \\ 3.2(\log_{10}(11.75h_m))^2 - 4.97 & f \ge 400MHz \end{cases}$ $C = 0$ Suburban environments $a(h_m) = (1.1\log_{10}(f) - 0.7)\,h_m - (1.56\log_{10}(f) - 0.8)$ $C = -2[\log_{10}(f/28)]^2 - 5.4$ Rural area $a(h_m) = (1.1\log_{10}(f) - 0.7)\,h_m - (1.56\log_{10}(f) - 0.8)$ $C = -4.78[\log_{10}(f)]^2 + 18.33\log_{10}(f) - 40.98$	f is in MHz, d is in km, and antenna heights are in m
COST 231-Hata	$PL = A + B\log_{10}\,d + C$ where $A = 46.3 + 33.9\log_{10} f - 13.82\log_{10} h_b - a(h_m)$ $B = (44.9 - 6.55\log_{10} h_b)$ $a(h_m) = (1.1\log_{10}(f) - 0.7)\,h_m - (1.56\log_{10}(f) - 0.8)$ C = 0 dB in dense urban; -5 dB in urban; -10 dB in suburban; -17 dB in rural	f is in MHz, d is in km, and antenna heights are in m